WATER AND SEDIMENT QUALITY SURVEY OF SELECTED INLAND SALINE LAKES

California Regional Water Quality Control Board
Central Valley Region
3443 Routier Road, Suite A
Sacramento, CA 95827-3098

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CENTRAL VALLEY REGION

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The staff involved in the
preparation of this report are:

Dennis W. Westcot, Senior Land and Water Use Analyst
Cassandra A. Enos, Assistant Water Resources Specialist
Jeanne E. Chilcott, Associate Land and Water Use Analyst
Kathryn K. Belden, Geologist Assistant

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EXECUTIVE SUMMARY

Because of the concern for the accumulation of certain trace elements in agricultural drainage water evaporation basins in the San Joaquin Valley, a water quality survey was conducted on 15 inland saline-sink lakes in the western United States to determine if such accumulation occurs under natural conditions and to what level. Water from seven saline lakes in California, five in Oregon, two in Nevada and one in Utah were sampled and analyzed for the five trace elements known to exist in high concentrations in the evaporation basins: arsenic, boron, molybdenum, selenium, and uranium.

The natural salt lakes varied greatly in mineral and trace element concentration and in almost all instances showed concentrations less than those found in the evaporation basins. The inland salt lakes did not appear to show the extent of salt buildup found in the evaporation basins. Although showing a significantly lower trace element concentration, the natural salt lakes displayed a characteristic similar to the evaporation basins in that they showed trace element accumulation at concentrations higher than seawater. This accumulation was greatest for arsenic, boron, molybdenum, uranium, and vanadium.

The selenium concentrations in the saline lakes were low and were less that the evaporation basins; however, the concentrations in many instances were greater than in seawater showing that some accumulation was occurring albeit small. Only one lake, Soda Lake showed an elevated selenium concentration in water. Soda Lake, in addition, was strongly elevated in three other trace elements tested: boron, molybdenum, and uranium. The concentrations found were similar to the high concentrations found in water in the evaporation basins. Because of this finding sediment samples were also taken from Soda Lake. Elevated levels of these four trace elements were also seen in the sediment of Soda Lake. Mono Lake also showed elevated levels of boron, uranium and arsenic in water, however, no sediment samples were available for comparison.

BACKGROUND

In early 1985, concern was expressed that sites within the San Joaquin Valley which were being used to store and evaporate agricultural subsurface drainage water were creating hazards to the environment. In response, between 1985 and 1989, Regional Board staff conducted water quality surveys of 27 evaporation basins in the Tulare Lake Basin of the San Joaquin Valley (Westcot et al., 1988a and b, and Chilcott et al., 1990a and b). Results showed wide variability in trace element levels in the evaporation basin water. In order to make any useful comparisons, baseline values were needed. However, no baseline values were available since these are man-made ponds. An alternative approach was to make an initial comparison to existing natural salt lakes as they pose the same type of environmental exposure and have concentrated trace elements through evaporation.

Several inland salt lakes in the western United States exist in environmental settings comparable to that of the evaporation basins. These lakes are in a semi-arid to arid climate such as that found in the Tulare Lake Basin of the San Joaquin Valley. Another similarity is that the lakes are closed systems with various natural inflows and no natural surface outflow. The settings are unlike the evaporation basins in that all inflows to the evaporation basins are subsurface agricultural return flows while inflows to the lakes are a combination of natural springs, streams, rainfall, runoff, and groundwater seepage. Primary water loss from both systems is by evaporation.

The minimum salinity (total dissolved solids) of the agricultural evaporation basin inflows measured in the San Joaquin Valley is 830 mg/L (Westcot et al., 1988a). Therefore, of the lakes surveyed only those that had a total dissolved solids (TDS) value greater than 830 mg/L were used to provide a comparison value. This criteria allowed data from 13 of the 15 lakes sampled to be used in the analysis.

STUDY AREA

A total of fifteen inland salt lakes were sampled for this study (Table 1 and Figure 1). All of the lakes sampled are located within the states of California, Oregon, Nevada and Utah. The lakes were chosen to represent typical closed salt sinks within the western United States. No attempt was made to correlate the site chosen with the local geology or to choose sites which had similar geologic characteristics. The goal was not to compare rates of salt and trace element buildup, but to develop a data base through which we might gain a better understanding of the types and scale of accumulation that would take place in these natural sites in comparison to trends we are seeing in the agricultural evaporation basins of the Tulare Lake Basin.

Table 1. Selected Inland Salt Lakes Surveyed and the Assisting Agencies

ID	Lake	State	County	Latitude/Longitude	Sampling Agency
1	Harney Lake	OR	Harney	43° 15' N 119° 10' W	Malheur National Wildlife Refuge, USFWS
2	Summer Lake	OR	Lake	42° 40' N 120° 50' W	Summer Lake Wildlife Refuge, ODFW
3	Abert Lake	OR	Lake	42° 30' N 120° 15' W	Summer Lake Wildlife Refuge, ODFW
4	Stone Corral Lake	OR	Lake	42° 30' N 119° 48' W	Sheldon-Hart Mountain Nat'l Wildlife Refuge, USFWS
5	Hart Lake	OR	Lake	42° 25' N 119° 51' W	Sheldon-Hart Mountain Nat'l Wildlife Refuge, USFWS
6	Goose Lake	CA	Modoc	41° 45' N 120° 30' W	Region 5, Central Valley RWQCB
7	Middle Alkali Lake	CA	Modoc	41° 20' N 120° 06' W	Dept. of Public Works, Modoc County
8	Honey Lake	CA	Lassen	40° 15' N 120° 20' W	Dakin Unit, Honey Lake Wildlife Area, DFG
9	Pyramid Lake	NV	Washoe	40° 00' N 119° 35' W	Region 5, Central Valley RWQCB
10	Walker Lake	NV	Mineral	38° 40' N 118° 43' W	Walker Lake Water District
11	Mono Lake	CA	Mono	37° 59' N 119° 08' W	San Joaquin District, DWR, Fresno
12	Castac Lake	CA	Kern	34° 45' N 118° 55' W	Tejon Ranch Company
13	Soda Lake	CA	San Luis Obispo	35° 13' N 119° 53' W	Patuxent Wildlife Research Center, USFWS
14	Salton Sea	CA	Imperial	33° 15' N 115° 50' W	Region 7, Colorado River RWQCB
15	Great Salt Lake	UT	Salt Lake	41° 10' N 112° 40' W	Region 5, Central Valley RWQCB

USFWS = U.S. Fish and Wildlife Service
RWQCB = Regional Water Quality Control Board
DFG = California Department of Fish and Game
ODFW = Oregon Department of Fish and Wildlife
DWR = California Department of Water Resources

DATA COLLECTION

Local agencies and managers of selected inland salt lakes were contacted and provided with acid washed polyethylene sample bottles. Four liters of water were collected at each location by the local agencies. After collection, the samples were shipped overnight to the Regional Board. Upon arrival at the Regional Board, one half of the sample was preserved to a pH of less than 2.0 using ultra-pure nitric acid fixation techniques. The preserved portion of the sample was analyzed for total recoverable trace elements. The unpreserved portion of the sample was filtered through a 0.45 micron filter. One half of the filtered sample was preserved to a pH of less than 2 using ultra-pure nitric acid fixation techniques and analyzed for selected dissolved trace elements. The remaining filtered sample was used for analysis of minerals. Table 2 contains a complete list of the analyses conducted.

Table 2. Analyses Performed on Inland Salt Lake Water Samples and the Minimum Detection Limits.

TRACE ELEMENTS	MDL	MINERALS	MDL	OTHER	MDL
B (µg/L)	20	Ca (mg/L)	0.1	Total Diss.	
Se (µg/L)	0.2	Mg (mg/L)	0.1	Solids (mg/L)	15
Mo (µg/L)	1	Na (mg/L)	0.5	EC (µmhos/cm)	10
U (µg/L)	1	K (mg/L)	0.01	pH (pH units)	0.1
As (µg/L)	4 - 25*	Cl (mg/L)	1	Hardness (mg/L)	1 - 2*
V (µg/L)	1	SO4 (mg/L)	2		
		HCO3 (mg/L)	2		
		CO3 (mg/L)	1 - 2*		
		Total Alk. (mg/L)	2		

MDL = Minium Detection limit.
* Detection limit varied based on sample composition.

Sediment samples were collected only from Soda Lake. Composite samples were taken at four different locations in the lake. Samples were taken of the top 0 - 7 cm (0 - 3 inch) of sediment . Samples were obtained with a plastic sampler that was rinsed several times with lake water prior to sampling. All sediment samples were placed in plastic bags and frozen until processing. All sediment samples were analyzed for standard minerals and trace elements.

RESULTS OF WATER QUALITY ANALYSES

Water quality samples from 15 inland salt lakes were collected between December 1988 and August 1989. The water in the lakes was primarily a saline sodium-

chloride water, similar to that of seawater (Figure 2). Mineral concentrations varied widely and total recoverable trace element concentrations commonly exceeded those of seawater (Table 3). A complete listing of the lake mineral water quality is shown in Table 4. Table 5 shows the trace element concentrations found in the lake samples.

Table 3. Concentration Ranges for Selected Constituents in 13 Inland Salt Lakes as Compared to Seawater and Evaporation Basins in the Tulare Lake Basin

Constituent	Inland Salt Lakes			Seawater 1/	Evaporation Basins 2/
	Minimum	Maximum	Geometric Mean		(Geometric Mean)
Na (mg/L)	340	89,000	4,560	10,500	8,850
SO4 (mg/L)	86	34,000	1,360	2,700	12,850
Cl (mg/L)	140	170,000	3,700	19,000	4,550
EC (µmhos/cm)	1,530	187,000	17,300	~50,000	32,100
TDS (mg/L)	970	360,000	13,900	31,000	31,850
B (mg/L)	3.7	420	17	4.5	23
Se (µg/L)	<0.2	490	0.6	<0.2	17
Mo (µg/L)	<1	5,340	54	10	1,050
As (µg/L)	17	16,000	280	3	44
U (µg/L)	1	820	30	3	340
V (µg/L)	2	280	23	2	27

1/ Seawater from Hem, J.D., 1985.
2/ Westcot et al., 1988a and b, and Chilcott et al. 1990a.

In order to ensure the data used for comparisons would be representative of saline sinks, only those lakes whose total dissolved solids concentration (TDS) was greater that 830 mg/L were included in the data analysis. This is the minimum concentration found in the Tulare Lake Basin evaporation pond inflows. Only two lakes had TDS values less than 830 mg/L, Summer and Hart Lakes in Oregon which contained 650 mg/L and 330 mg/L, respectively. As shown in Table 3 for the remaining 13 lake samples, total dissolved solids (TDS) values ranged from 970 to 360,000 mg/L with a geometric mean of 13,900 mg/L. The geometric mean concentration for total dissolved solids for the Tulare Lake Basin agricultural evaporation basins was 31,850 mg/L or approximately twice the geometric mean found for the natural salt lakes. The range of concentrations in the inland salt lakes, however, was similar to those found in the evaporation basins (Westcot et al., 1988a).

Total recoverable selenium in water samples from inland saline lakes was found in low concentrations. Values ranged from <0.2 to 490 µg/L, with a geometric mean of 0.6 µg/L. Only one lake, Soda Lake (490 µg/L Se) showed a concentration above the EPA National Ambient Water Quality Criteria to Protect Freshwater Aquatic Life of 5 µg/L (EPA, 1987). Comparison with freshwater criteria however may not be valid since these are saline lakes. The saltwater criterion for selenium of 71 µg/L (EPA,

Figure 2. Chemical Composition of Selected Inland Salt Lake Water as Compared to Seawater

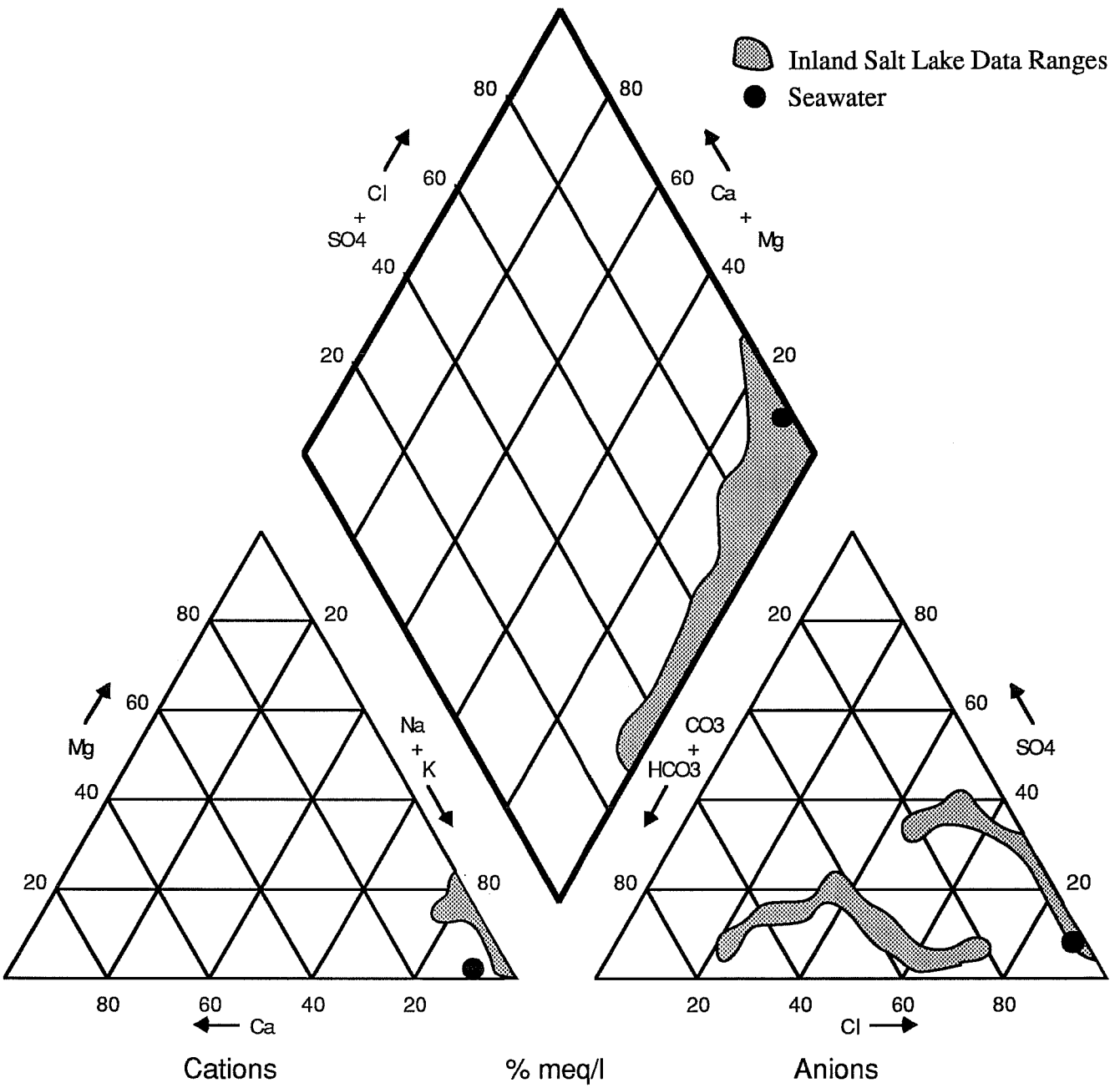

Table 4. Mineral Water Quality Data for Selected Inland Saline Lakes of the Western United States.

Lake Site	Sample Date	EC umhos/cm	pH	Ca	Mg	K	Na	Cl	SO4	HCO3	CO3	Total Alk	Calculated TDS	TDS	Hardness
				(mg/L)											
Salton Sea, CA	12/8/88	52,320	7.6	960	1100	200	11,000	17,000	10,000	180	<1	180	42,000	40,300	6,900
Harney Lake, OR	12/6/88	4,360	9.1	11	8.6	49	970	680	210	900	<1	900	2,600	2,400	60
Honey Lake, CA	1/3/89	6,450	9.2	13	4.1	50	1,500	780	650	1,600	<1	1,600	4,200	3,800	50
Walker Lake, NV	1/22/89	13,910	9.4	8.6	130	160	3,400	2,800	2,700	2,300	<1	2,300	9,400	10,300	530
Lake Abert, OR	1/27/89	49,900	9.8	1.9	0.7	730	19,000	16,000	990	15,000	<1	15,000	50,000	44,100	8
Summer Lake, OR*	1/29/89	840	8.2	2.8	1.7	13	170	69	21	240	<1	240	650	400	13
Castac Lake, CA	1/31/89	27,640	9.3	24	430	8	7,600	6,600	6,900	1,800	<1	1,800	28,000	22,400	1,800
Soda Lake, CA	3/15/89	187,000	7.6	220	14,000	92	89,000	170,000	34,000	450	<1	450	360,000	307,500	58,000
Middle Alkali Lake, CA	3/21/89	1,530	9.1	1.5	1.4	2	340	140	110	270	120	420	970	900	4
Goose Lake, CA	4/18/89	2,040	9.1	9.3	3.8	33	430	160	86	660	120	740	1,300	1,100	40
Stone Corral Lake, OR	7/4/89	10,610	9.4	9.5	74	94	3,000	1,300	440	1,600	2,000	4,700	8,200	8,200	310
Mono Lake, CA	7/10/89	87,760	9.7	7.8	40	1,800	30,000	19,000	12,000	0	18,900	31,500	82,000	91,000	170
Hart Lake, OR*	8/10/89	460	8.4	28	12	7	42	11	16	150	3	153	330	200	120
Great Salt Lake, UT	8/29/88	102,000	8.3	180	2,500	1,400	25,000	46,000	4,800	360	<1	360	84,000	80,100	11,000
Pyramid Lake, NV	8/30/88	7,970	9.2	7.4	110	130	1,600	2,100	260	1,100	<1	1,100	4,800	4,700	470
Seawater**				410	1,350	390	10,500	19,000	2,700	142	<1	142		34,400	6,550
Minimum		1,530	7.6	1.5	0.7	2	340	140	86	180	<1	180	970	900	4
Geometric Mean		17,300	9.0	18	58	97	4,560	3,700	1,360	580	3	1,456	13,900	13,054	317
Maximum		187,000	9.8	960	14,000	1,800	89,000	170,000	34,000	15,000	18,900	31,500	360,000	307,500	58,000

* Not considered in the data analysis as salinity data showed this lake to be in a freshwater condition at the time of sampling.

** Hem, J.D., 1985. Seawater data not included in the data analysis.

Table 5. Total Recoverable Trace Element Water Quality Data for Selected Inland Saline Lakes of the Western United States.

Lake Site	Sample Date	B (mg/L)	Se	Mo	U (ug/L)	As	V	
Salton Sea, Ca	12/8/88	9.7	1.5	6	26	17	11	
Harney Lake, OR	12/6/88	6.9	0.6	37	4	290	40	
Honey Lake, CA	1/3/89	6.6	0.6	210	56	420	280	
Walker Lake, NV	1/22/89	20	<0.2	260	140	920	10	
Lake Abert, OR	1/27/89	57	<0.2	98	29	1,300	82	
Summer Lake, OR*	1/29/89	2.7	0.3	1	2	59	200	
Castac Lake, CA	1/31/89	11	0.8	69	200	970	27	
Soda Lake, CA	3/15/89	64	490	5,340	820	26	38	
Middle Alkali Lake, CA	3/21/89	10	<0.2	<1	1	270	6	***
Goose Lake, CA	4/18/89	3.7	<0.2	13	3	35	33	
Stone Corral Lake, OR	7/4/89	30	0.7	34	23	1,200	120	
Mono Lake, CA	7/10/89	420	1.7	110	540	16,000	8	
Hart Lake, OR*	8/10/89	0.42	0.5	1	5	58	56	
Great Salt Lake, UT	8/29/88	8.9	1.1	34	7	83	4	
Pyramid Lake, NV	8/30/88	9.8	0.3	47	17	79	19	
Seawater**		4.5	<0.2	10	3	3	2	
Minimum		3.7	<0.2	<1	1	17	2	
Geometric Mean		17	0.6	54	30	280	23	
Maximum		420	490	5,340	820	16,000	280	

* Not considered in the data analysis as salinity data showed this lake to be in a freshwater condition at the time of sampling.

** Hem, J.D., 1985. Seawater data not used in the data analysis.

*** Not considered in data analysis as excessive sediment interfered with analytical recovery.

1987) is also exceeded in Soda Lake, however no analysis of the applicability of the criterion to saline lakes has been conducted. The second highest selenium concentration of 1.7 µg/L was found in Mono Lake while the Salton Sea showed 1.5 µg/L in this survey.

The selenium concentrations found in the inland saline lakes, except for Soda Lake, were less than those found in the evaporation basins of the Tulare Lake Basin. The evaporation basins showed selenium concentrations of >10 µg/L in 70 percent of the 7,160 ponded acres. However, selenium concentrations in the evaporation basins ranged from 0.2 to 1,940 µg/L with a geometric mean of 17 µg/L (Westcot et al., 1988a), considerably higher than the 0.6 µg/L geometric mean found in this survey of inland saline lakes.

Total recoverable uranium in the inland saline lakes ranged from 1 to 820 µg/L. The geometric mean of 30 µg/L in the saline lakes is lower than the geometric mean for total recoverable uranium of 340 µg/L found in the evaporation basins in the Tulare Lake Basin. The evaporation basins showed a concentration range from 30 to 11,000

µg/L with less than 10 percent of the presently ponded acreage showing a concentration less than 100 µg/L uranium (Westcot et al. 1988b). Two lakes, Soda Lake and Mono Lake in California had a uranium concentration that exceeded the Canadian standard of 500 µg/L for Protection of Aquatic Life in Saltwater (Environment Canada, 1979).

Total recoverable molybdenum concentrations in saline lake waters ranged from <1 to 5,340 µg/L with a geometric mean of 54 µg/L (Table 3). The geometric mean (54 µg/L) exceeds the freshwater aquatic life protection level of 19 µg/L which was established in the San Joaquin River (RWQCB, 1988). Ten of the 13 saline lakes exceeded this freshwater protection level, however, its application to saline lakes is unknown and no value is available for saltwater. The geometric mean of 54 µg/L is lower than the geometric mean for total recoverable molybdenum of 1,050 µg/L in the evaporation basins in the Tulare Lake Basin. The evaporation basins showed a concentration range from 58 to 39,900 µg/L (Westcot et al., 1988a) with none of the ponded acreage showing a concentration less than the geometric mean of the measured natural inland saline lakes.

Total recoverable arsenic values in water samples from the saline lakes were relatively high. Arsenic ranged from 17 to 16,000 µg/L with a geometric mean of 280 µg/L (Table 3). This geometric mean (280 µg/L) is higher than the water quality criterion for protection of freshwater aquatic life (190 µg/L) and exceeds the criterion for protection of saltwater (marine) aquatic life(36 µg/L) (EPA, 1985). No analysis has been done, however, on the applicability of the criteria to inland saline lakes. Ten of the thirteen saline lakes exceeded the EPA saltwater aquatic life criteria. In addition, the two lakes not considered in the analysis, because they showed they were in a freshwater condition at the time of sampling, also exceeded the EPA saltwater aquatic life criterion. The geometric mean for the saline lakes (280 µg/L) was also greater than the mean for seawater (3 µg/L). The geometric mean of 44 µg/L total recoverable arsenic found in the evaporation basins in the Tulare Lake Basin is lower that the geometric mean for the measured inland salt lakes. The evaporation basins showed a concentration range from <1 to 13,000 µg/L (Westcot, et al., 1988a) with only about 10 percent of the ponded acreage showing a concentration greater that the geometric mean of the measured inland saline lakes.

Total recoverable vanadium concentrations ranged from 2 to 280 µg/L in the saline lake water. The geometric mean for vanadium in the saline lakes (23 µg/L) compared favorably with the geometric mean found in the evaporation basins in the Tulare Lake Basin (27 µg/L) (Chilcott et al., 1990a). The range of vanadium concentrations in the evaporation basins (1 to 490 µg/L) was greater that the range for the saline lakes. In all cases, the vanadium concentrations were elevated over a background seawater

concentration (2 µg/L). No guidelines are currently available to assess potential impacts on aquatic life for the vanadium concentrations reported.

The trace element found at the highest concentrations was boron. Boron ranged from 3.7 to 420 mg/L, with a geometric mean of 17 mg/L (Table 3). This geometric mean is approximately 16 mg/L greater than the criterion for agricultural water use of 0.7 mg/L (Ayers and Westcot, 1985), and over three times the concentration in seawater (4.5 mg/L). Similarly high concentrations of boron were found in the evaporation basins in the Tulare Lake Basin. Total recoverable boron concentrations in the evaporation basins ranged from 2.5 to 840 mg/L with a geometric mean of 23 mg/L (Westcot et al., 1988a). Over 55 percent of the presently ponded area in the evaporation basins exceeds a total recoverable boron concentration of 25 mg/L (Westcot et al., 1988a).

The inland salt lakes varied greatly in the concentrations of selected trace elements tested for. Although varying, the salt lakes displayed a characteristic similar to the evaporation basins in the Tulare Lake Basin in that they showed higher concentrations than seawater for certain trace elements. This accumulation appears to be true for arsenic, boron, molybdenum, uranium, and vanadium, but does not hold for selenium. The reasons for the difference with selenium may be connected to the geology of the area immediately surrounding the evaporation basins in the Tulare Lake Basin and that surrounding each inland salt lake.

Two lakes had consistently high values for trace elements, Soda and Mono Lakes. Soda Lake had the highest TDS value (360,000 mg/L) and the highest concentrations of selenium, molybdenum and uranium (490 µg/L, 5,340 µg/L and 820 µg/L, respectively) and was elevated in boron (64 mg/L). Mono lake was the most alkaline lake with a total alkalinity of 31,500 mg/L. Mono Lake also had the highest concentrations of total recoverable arsenic and boron (16,000 µg/L and 420 mg/L, respectively) and showed an elevated level of uranium (540 µg/L).

In order to determine if arsenic, uranium, and vanadium were in a soluble or insoluble form, dissolved arsenic, uranium, and vanadium were analyzed for selected lakes (Table 6). By comparing the total recoverable values with the dissolved values it is possible to estimate whether these trace elements were present in a soluble form or in a form attached to particulate matter. The geometric mean for dissolved arsenic was 180 ug/L, similar to the geometric mean for total recoverable arsenic (200 µg/L). Only Harney Lake was found to have considerably higher total recoverable arsenic than dissolved arsenic. Harney Lake had a total recoverable arsenic value of 290 µg/L and a dissolved value of 170 µg/L, indicating that a large portion of the arsenic in Harney Lake may be attached to particulate matter. The geometric mean for dissolved uranium was 36 µg/L, almost equal to the geometric mean for total uranium

(37 µg/L). No lakes were found to have greatly different total recoverable uranium than dissolved uranium. Similar to uranium, total recoverable vanadium concentrations were comparable to dissolved concentrations found for each lake. Excessive sedimentation interfered with total vanadium recoveries in Middle Alkali Lake so the data could not be used for comparison.

Table 6. Comparison of Total and Dissolved Values for Arsenic, Uranium, and Vanadium for Selected Inland Salt Lakes in the Western United States.

LAKE	Dissolved As µg/L	Total As µg/L	Dissolved U µg/L	Total U µg/L	Dissolved V µg/L	Total V µg/L
Goose Lake	33	35	ND	-	ND	33
Middle Alkali Lake	200	270	1	1	**	**
Soda Lake	26	26	830	820*	35	38
Castac Lake	960	970	180	200	13	27
Lake Abert	1,400	1,300*	29	29	76	82
Walker Lake	830	920	140	140	9	11
Salton Sea	17	17	28	26*	ND	ND
Harney Lake	170	290	3	4	35	40
Honey Lake	400	420	50	56	273	283
Minimum	17	17	1	1	9	11
Median	200	290	40	43	35	38
Geometric Mean	180	200	36	37	38	45
Maximum	1,400	1,300	830	820	273	283

* Total values, although less than the dissolved concentrations are within standard laboratory error allowance of 10 percent.

** Not used in data calculations as excessive sediment interfered with total recoveries.

ND - No data available

These preliminary results indicate that, with the exception of arsenic in Harney Lake, and vanadium in Castac Lake, almost all of the arsenic, uranium, and vanadium in the inland salt lakes sampled was in the soluble form. It must be recognized that each lake has a different particulate matter concentration, thus it is not possible to make comparisons between sites.

RESULTS OF SEDIMENT ANALYSES

Sediment data was only collected at Soda Lake. Four composite samples were collected from different sections of the lake. Data for trace element levels in Soda Lake sediment is presented in Table 7. All of the trace elements, with the exception of vanadium, were found at concentrations above the baseline values for the western United States as determined by Shacklette and Boerngen, 1984 (Table 8), but data was insufficient to conduct a statistical analysis. The geometric mean for arsenic in

Table 7. Sediment Analyses for Soda Lake in the Carrizo Plain of California.

SITE	DATE	Ca	Mg	Na	K	P	Al	Fe	Mn	Ti	Cu	Zn	Ni	Mo
		%									mg/Kg			
Soda Lake West	6/7/89	1.51	1.70	3.64	0.39	0.047	1.28	0.38	0.020	0.046	9	34	19	15
Soda Lake South	6/7/89	1.48	2.04	2.13	1.02	0.077	3.90	1.77	0.052	0.081	27	103	45	10
Soda Lake North	6/7/89	4.48	2.33	7.69	0.45	0.093	2.05	0.33	0.028	0.042	25	88	43	196
Soda Lake Main	6/7/89	0.89	1.89	5.82	0.37	0.057	1.45	0.40	0.020	0.040	12	47	25	65
Geometric Mean		1.73	1.98	4.32	0.51	0.066	1.96	0.55	0.028	0.050	16	62	31	37
Baseline 1/											21	55	15	0.85
Evaporation Basins 2/ (geometric mean)											18	48	26	12

SITE	DATE	U	Cd	Cr	Sr	B	Ba	Pb	V	As	Se	TOC	Sat Ext B	Sat
		mg/Kg										%	mg/L	%
Soda Lake West	6/7/89	37	2	54	282	104	125	16	32	4.4	1.16	1.5	33.9	48.0
Soda Lake South	6/7/89	6	4	18	155	88	217	40	70	5.6	0.76	1.5	2.0	72.1
Soda Lake North	6/7/89	170	6	29	628	321	53	27	73	9.7	110.85	2.6	67.3	68.9
Soda Lake Main	6/7/89	14	3	41	131	117	99	22	39	6.5	16.7	1.9	41.9	46.8
Geometric Mean		27	3	33	245	136	109	25	50	6.3	6.36	1.8	20.9	57.8
Baseline 1/		2.5		41	200	23	580	17	70	5.5	0.23			
Evaporation Basins 2/ (geometric mean)		9.3	0.45	39	252	112	150	8.6	56	8.7	0.52	0.7		

1/ Shacklette and Boerngen, 1984. Baseline is the expected 95 percentile range for the Western United States.
2/ Chilcott, et al., 1990b.

Values reported on a dry weight basis.

sediment from Soda Lake was found at 6.3 mg/Kg, slightly exceeding the baseline value of 5.5 mg/Kg. The geometric mean for molybdenum of 37 mg/Kg not only exceeded the baseline value (0.85 mg/Kg) but also exceeded the maximum value expected in soils in the western United States (7 mg/Kg) (Shacklette and Boerngen, 1984). This elevated level is consistent with the high concentrations of molybdenum found in water from Soda Lake (Table 5). There was high variability among the four sample sites (Table 8), however, none of the samples had a concentration less than the maximum value expected in soil in the western United States.

Table 8. Comparison of Soda Lake Sediment Trace Element Levels with Concentrations Found in Evaporation Basin Sediments and Soils of the Western United States.

Element	Evaporation Basins 1/	Baseline 2/ geometric mean (range)	Soda Lake
Arsenic (mg/Kg)	8.7 (1.4-181)	5.5 (<0.10-97)	6.3 (4.4-9.7)
Boron (mg/Kg)	112 (19-472)	23 (<20-300)	136 (88-321)
Molybdenum (mg/Kg)	12 (1.3-283)	0.85 (<3-7)	37 (10-196)
Selenium (mg/Kg)	0.52 (0.05-15)	0.23 (<0.1-4.3)	6.4 (0.76-110.9)
Uranium (mg/Kg)	9.3 (1.0-290)	2.5 (0.68-7.9)	27 (6-170)
Vanadium (mg/Kg)	56 (11-181)	70 (7-500)	50 (32-73)
Nickel (mg/Kg)	26 (3.8-114)	15 (<5-700)	31 (19-45)

1/ Chilcott et al., 1990b.
2/ Baseline values for soils of the Western United States (Shacklette and Boerngen, 1984).

The geometric mean for nickel at Soda Lake was found to be (31 mg/Kg), approximately twice as high as the baseline value (15 mg/Kg) and slightly higher than the geometric mean for the evaporation basins (26 mg/Kg) (Chilcott et al. 1990b). The geometric mean for selenium (6.4 mg/Kg) at Soda Lake exceeded the baseline value (0.23 mg/Kg) and the maximum value (4.3 mg/Kg) for the western United States (Shacklette and Boerngen, 1984). Boron and uranium were also analyzed. Comparison to sediment values from evaporation basins in the Tulare Lake Basin

shows that both trace elements had means above the evaporation basin means. Soda Lake had a geometric mean boron concentration of 135 mg/Kg, slightly higher than the evaporation basin mean of 112 mg/Kg (Westcot et al., 1988a), but much greater than the baseline value given by Shacklette and Boerngen (1984) of 23 mg/Kg. However, Shacklette and Boerngen (1984) had noted maximum values above those found in Soda Lake. The mean uranium concentration was 27 mg/Kg in Soda Lake, about three times greater than the mean for the evaporation basins of 9.3 mg/Kg (Chilcott et al., 1990b), an order of magnitude higher than the baseline value suggested by Shacklette and Boerngen (1984) and over 3 times the highest background soil concentration (7.9 mg/Kg) noted by Shacklette and Boerngen (1984).

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